According to Eq. (7), volume scattering should increase with the perpendicular baseline, whereas small baselines should reduce the sensor sensitivity to volumetric decorrelation. To quantitatively determine the volume scattering in volcanic deposits, we can assess the penetration depth δ_p which depends on pyroclast textural and dielectric properties (Kruse, Mora, Ramirez, & Alvarado, 2010; Russel & Stasiuk, 1997). For a homogeneous medium, it may be approximated by (Massonnet & Souyris, 2008):

$$\delta_p \approx \frac{\lambda}{2\pi}\frac{\sqrt{\varepsilon'}}{\varepsilon''} \tag{9}$$

where ε' and ε'' are the real and imaginary parts of the complex dielectric constant of the medium. ε' describes the ability of matter to store energy, whereas ε'' represents the amount of lost energy. They are directly related to mineralogy and moisture content, and may vary rapidly in space and time. Their ratio is defined as the loss tangent:

$$\tan\delta_e = \frac{\varepsilon''}{\varepsilon'}. \tag{10}$$

δ_e varies inversely as the value of the frequency: low frequency waves (L and P bands) propagate deeper into the medium than high ones (C and X bands), but in turn, the resolution decreases (Gómez-Ortiz et al., 2006). The rapid increase in dielectric constant with volumetric moisture constant tends to decrease the penetration depth (Rust & Russel, 2001). Moreover, the magnitude of the permittivity displays a strong dependence on ground porosity (Russel & Stasiuk, 1997; Rust, Russel, & Knight, 1999) and bulk density (Campbell & Ulrichs, 1969).

2.3. Temporal decorrelation

$\gamma_{temporal}$ refers to changes in target scattering properties between two acquisitions. Temporal decorrelation may be caused by vegetation growth or modification of soil dielectric properties. In volcanic areas, landscape changes are primarily due to surface deformations associated with volcano activity. The longer the timeslot between two images (temporal baseline), the higher the decorrelation. Modeling this effect is not straightforward. If anthropogenic changes generally cannot be assessed quantitatively, natural processes may be accounted for in models. Zebker and Villasenor (1992) showed that:

$$\gamma_{temporal} = \exp\left\{-\frac{1}{2}\left(\frac{4\pi}{\lambda}\right)^2\cdot\left(\sigma_x^2\sin^2\theta+\sigma_z^2\cos^2\theta\right)\right\} \tag{11}$$

with σ_x and σ_z the horizontal and vertical standard deviations, respectively. For incidence angles less than 45°, Eq. (11) shows a greater sensitivity to vertical than to horizontal changes. So, the signal decorrelates faster over surfaces displaying significant volume scattering, such as forests, and at shorter wavelengths.

3. Studied area

The *Piton de la Fournaise* is a basaltic shield volcano located in the ESE part of Reunion Island in the Indian Ocean roughly 800 km east of Madagascar (Fig. 1). It has been active for 0.15 My (Gillot & Nativel, 1989) and is still considered as one of the world's most active volcanoes. The central cone within the *Enclos Fouqué* depression is 2635 m high and 3 km large at its base, with a mean slope of 15–20°. The summit cone shows two collapsed structures: the Dolomieu crater in the east and the Bory crater in the west. The recent activity of the volcano, mainly effusive, is concentrated in the Dolomieu crater and along two curved rift zones which diverge towards the north–east (N10°) and the south–east (N170°) from the summit (Bachèlery, 1981), allowing the transport of magma outside the *Enclos Fouqué* down to the ocean. The morphology of the volcano results from consecutive lava flows, ash deposits and geological phenomena such as collapses and landslides. Hence changes to the surface are mainly caused by the deposition of young pyroclasts and flows associated with recent eruptive events, by erosion, but also by vegetation growth in the older parts of the edifice.

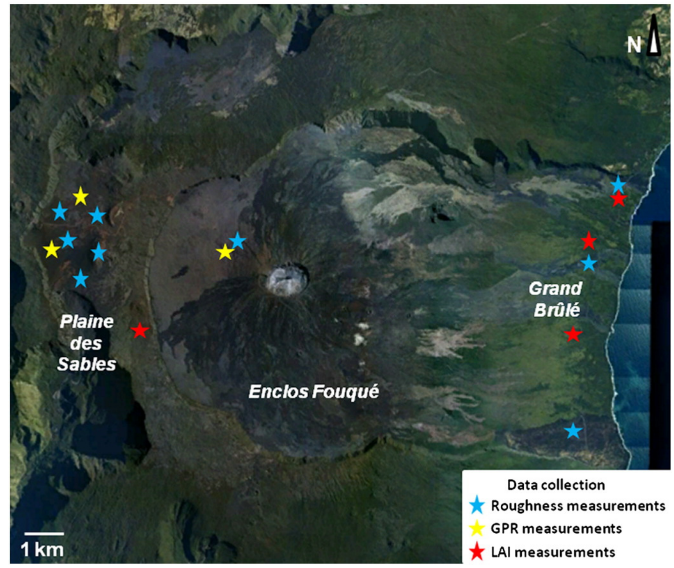

Fig. 1. Visible image of the *Piton de la Fournaise* showing the location of the *Plaine des Sables*, the *Enclos Fouqué* and the *Grand Brûlé* (BDOrtho®, IGN, 2008).

The *Piton de la Fournaise* offers a wide range of volcanic terrains and vegetation canopies. Such an environment offers a unique opportunity to analyze and better understand the causes of coherence loss. Three main regions characterized by different landscape typologies have been investigated (Fig. 2):

1. The *Plaine des Sables* (average elevation of 2290 m) located on the west part of the volcano is relatively flat. It is mainly covered with lapilli deposits, sometimes interlinked with historical slabby pahoehoe lava flows. They contain a series of closely spaced slabs, a few meters across and a few centimeters thick. The oldest lava flows near the *Rempart de Bellecombe* have been colonized by sparse vegetation dominated by shrubs.
2. The *Enclos Fouqué* (average elevation of 2270 m) is filled by a large lava field essentially formed by pahoehoe lava, the surface of which can be smooth, ropy or even bumpy, and a'a lava flows that look darker and display fragmentary, spiny surfaces with irregularly shaped vesicles.
3. The *Grand Brûlé* (average elevation of 100 m) located on the East flank of the volcano exhibits a juxtaposition of several individual a′a and pahoehoe flows that are partly covered by vegetation such as lichens, ferns or trees.

4. Data sets and survey setup

4.1. ALOS/PALSAR data

The PALSAR (polarimetric Phased Array L-band Synthetic Aperture Radar) instrument has been designed to provide consistent earth's surface observations at fine resolution. It operates at 1.270 GHz (L-band, 23.6 cm) in five modes with different off-nadir angles: Fine Beam Single polarization (FBS), Fine Beam Dual polarization (FBD), polarimetric mode (POL), ScanSAR mode, and Direct Transmission (DT). The viewing angle ranges from 9.9° to 50.8° for both the FBS and the FBD modes, and from 9.7° to 26.2° in the full-polarimetric mode (Furuta, Shimada, Tadono, & Watanabe, 2005; Rosenqvist, Shimada, Ito, & Watanabe, 2007). PALSAR performs cloud-free and day-and-night surface measurements with a 46-day repeat pass cycle. It can measure topography,